

Giant Goos-Hanchen effect and focusing of gaussian light beam by one-dimensional photonic crystal with modulated band gap

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Abstract— We present the theoretical and experimental studies of the giant Goos-Hanchen effect and the effect of focusing of light beam in one-dimensional photonic crystals with spatial modulation of photonic band gap position. We show that the photonic crystal with slow exponentially modulated band gap applies the second-order phase modulation to the reflected light and can focus or defocus the light beam.

Keywords—photonic crystals, Goos-Hänchen effect, focusing of light, modulated band gap.

I. INTRODUCTION

One-dimensional (1D) photonic crystals (PhCs) are well-known for decades. The simplest case of PhC is the array of alternating dielectric layers of two types and these PhCs are known as Bragg mirrors. Recent progress in the fabrication technologies opens the possibility to produce samples of large numbers of periods (hundred and more). These thick samples allow to slowly modulate the photonic band gap along the sample. Linearly modulated 1D PhCs referred as chirped mirrors are used in ultrafast optics to compress short laser pulses and in creation of broadband and omnidirectional reflectors [1]. In this work we present the PhCs with exponential profile of photonic band gap. Exponential profile applies the second-order phase modulation [2] which allows to focus light beams by 1D multilayer structures and enhances surface effects like Goos-Hänchen effect.

II. METHODS

The reflection of the light beam from photonic crystal was calculated by transfer matrix method. The optical thickness of each layer $\Lambda = nd$ increases with depth z of the PhC by the law:

$$\frac{1}{\Lambda(z)} = \frac{1}{\Lambda} \left(1 + \frac{u_0}{z_0} e^{-z/z_0} \right) \quad (1)$$

where z_0 , u_0 – modulation parameters. The physical thicknesses d_1 , d_2 and the scheme of the sample are shown in fig. 1.

The samples of 1D PhCs were made by electrochemical etching of silicon followed by the thermal annealing. The experimental procedure is described elsewhere [3]. The sample consists of 1100 alternating layers with constant refractive

indexes of $n_1=1.32$, $n_2=1.48$ and modulation parameters $z_0=40$ μm , $u_0=8$ μm , $\Lambda=210$ nm.

The experimental observation of the focusing effect was performed by setup based on He-Ne laser (wavelength of 632.8 nm, power of 1 mW). The laser beam was expanded by the telescope to width of 2.1 mm and focused on the sample surface by lens ($f=10\text{cm}$). The distance between lens and sample was variable to study cases of focused, convex and concave incident beams.

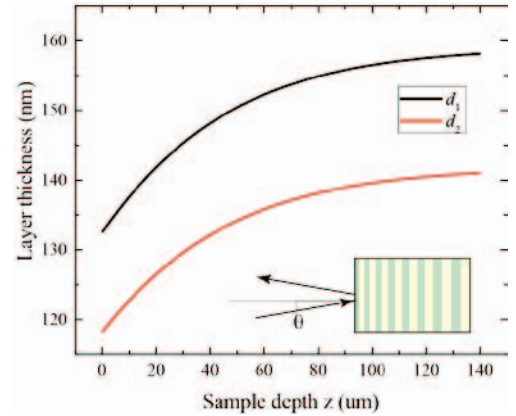


Fig. 1. The exponential modulation of the physical thickness of the sample layers. The thicknesses of layers of two types are d_1 and d_2 . Inset: the scheme of experiment: the light enters the sample at the angle of θ in the Bragg geometry.

III. RESULTS AND CONCLUSION

The focusing of light by 1D PhC with exponential profile of the photonic band gap is experimentally observed. The concave Gaussian beam is focused after the reflection of the sample at the distance of about 1 cm. The measured Goos-Hänchen shift is about 100 μm .

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